Experimental Observations of CSR Bursts in Rings

Boris Podobedov, BNL

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BROOKHAVEN
NATIONAL LABORATORY

Scope, Outline and Caveats

- CSR: C is for Coherent -> *Power ~ N^2*
- CSR bursts are reported at

  ALS, BESSY-II, MAX-I, NSLS VUV, SURF,...
- In this talk I attempt
  - Introduce experimental methods and review results
  - Stimulate a discussion
- I do NOT attempt
  - Be comprehensive

References

ALS

- BROADBAND SELF-AMPLIFIED SPONTANEOUS COHERENT SYNCHROTRON RADIATION IN A STORAGE RING, J. Byrd et al, EPAC02
- OBSERVATION OF BROADBAND SELF-AMPLIFIED SPONTANEOUS COHERENT TERAHERZ SYNCHROTRON RADIATION IN A STORAGE RING, J. Byrd et al, to appear in PRL

BESSY-II

- COHERENT mm-RADIATION EXPERIMENTS AT THE BESSY II STORAGE RING, M. Abo-Bakr et al, EPAC00
- POWERFUL, STEADY STATE, COHERENT SYNCHROTRON RADIATION AT BESSY II, M. Abo-Bakr et al EPAC02
- STEADY-STATE FAR-INFRARED COHERENT SYNCHROTRON RADIATION DETECTED AT BESSY II, M. Abo-Bakr et al, PRL 88-25, 2002

MAX-1

- OBSERVATION OF COHERENTSYNCHROTRON RADIATION FROM A 1 MM ELECTRON BUNCH AT THE MAX-I STORAGE RING, A. Andersson et al, SPIE vol. 3775, 1999

NSLS VUV

- INVESTIGATION OF COHERENT EMISSION FROM THE NSLS VUV RING, G. L. Carr et al, PAC99
- TWO-BEAM INTERFERENCE OF LONG WAVELENGTH SYNCHROTRON RADIATION, G. L. Carr et al, PAC01
- LONGITUDINAL DENSITY MODULATION OF UNSTABLE BUNCHES EMITTING COHERENT IR, B. Podobedov et al, PAC01
- OBSERVATION OF COHERENT SYNCHROTRON RADIATION FROM THE NSLS VUV RING, G. L. Carr et al, NIM-A 463, 387, 2001
- ORIGIN OF LONGITUDINAL DENSITY MODULATION OF UNSTABLE BUNCHES IN THE NSLS VUV RING, B. Podobedov et al, EPAC02
- COHERENT MICROWAVE SYNCHROTRON RADIATION IN THE VUV RING, S. L. Kramer and B. Podobedov, EPAC02
- DIRECT OBSERVATION OF BEAM IMPEDANCE ABOVE CUT-OFF, S.L. Kramer, to appear in PRST-AB

SURF

- SIMULATION INVESTIGATIONS OF THE LONGITUDINAL SAWTOOTH INSTABILITY AT SURF, K. Harkay , K.-J. Kim, and N. Sereno, PAC01
- SPONTANEOUS COHERENT MICROWAVE EMISSIONS AND THE SAWTOOTH INSTABILITY IN A COMPACT STORAGE RING, U. Arp et al, PRST-AB 4, 054401, 20001

Ring Parameters

	ALS	BESSY-II	MAX-1	NSLS VUV	SURF
Circumf. m	197	240	32.4	51	5.3
Energy, GeV	1.9	1.7	0.5	0.74	0.25
σ_{rms}, mm	7	5	4	150	80
λ due to CSR cutoff, mm	8	4		12.5	67
I_{bunch}, mA	10	15	3	200	90

Parameter space is infinite

These are just rough examples

Experimental Methods & Measurements Reported

	experiment	ALS	BESSY-II	MAX-1	NSLS VUV	SURF
Coherent Emissions	RF & MW techniques	X	X		X	X
	Interferometry	X	X	X	X	
	Polarization			X	X	
"e-beam"	BPM signal analysis				X	X
	Average Bunch Shape	X	X	X	X	X
	Photo-diodes + scopes etc Single-Shot Bunch Shape		X		X	X

Streak Cameras, etc

RF & MW Techniques for Emissions Studies

Advantages

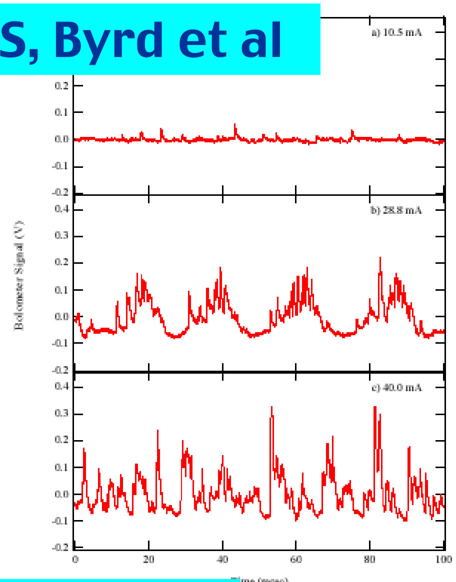
- Time and Freq. Domain
- Plenty of tools/hardware
- Extends to low frequencie
- Trivial pol msrmnt

Challenges

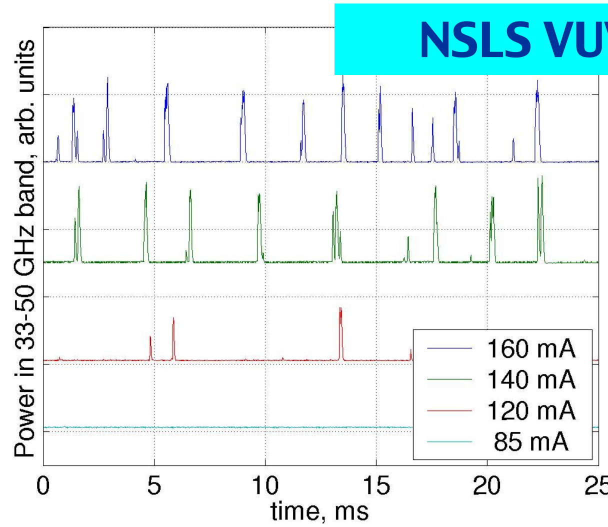
- Painful to cover large BW
- Expensive above 26 GHz
- Dynamic range & rise-
- Products

Emission Bursts

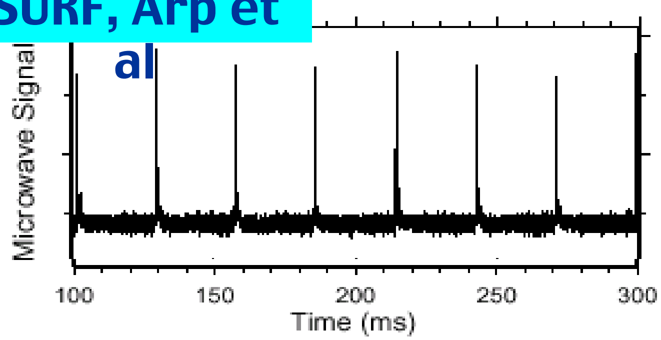
ALS, Byrd et al



NSLS VUV



SURF, Arp et al

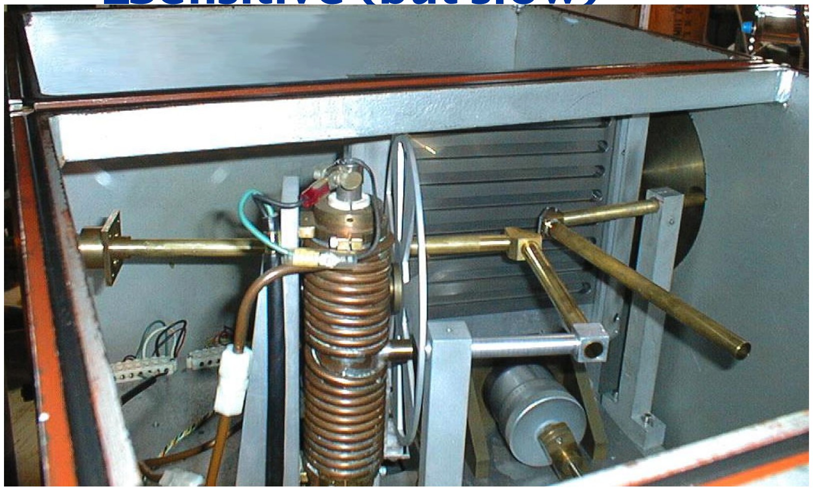


- Quasi–Periodic or chaotic bursts
- Strongly condition–dependent
- Duration ~ T_{synch}
- Separation ~ T_{damp}
- *Power* ~ N^2 well above N_{thresh}

Interferometry

Advantages

- BW extends into THz range
- Convenient (no filter change)
- Sensitive (but slow)



Challenges

- Essentially freq. domain
- Slow measurement
- Bursting data hard to interpret
- Ratio calculations

lamellar grating interferometer at NSLS U12IR

spectral range ~1-100 cm^{-1}

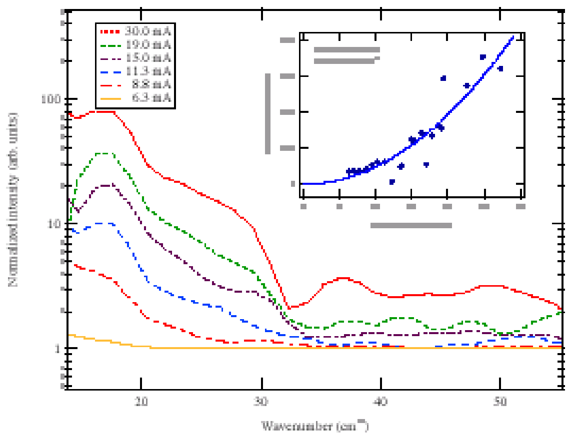
0.25 cm^{-1} resolution

"light pipe" and mirror optics

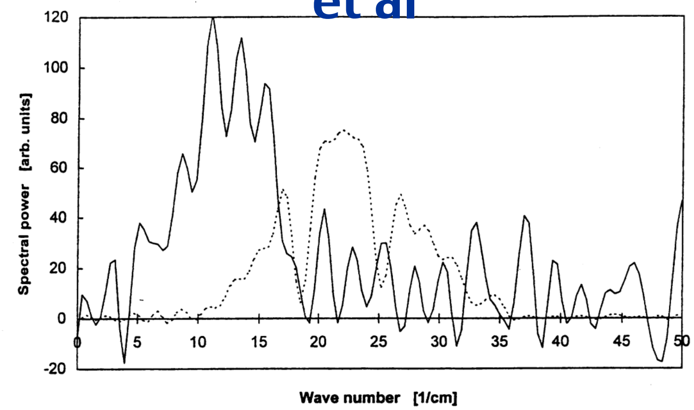
thermal IR detector (bolometer)

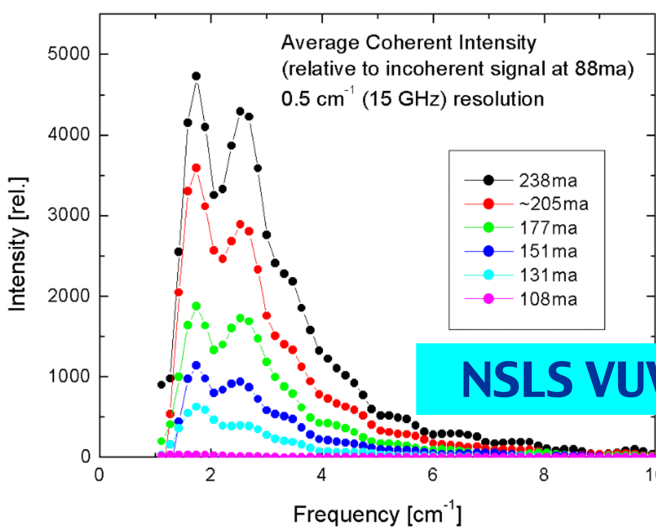
Interferometry Results

ALS, Byrd et al



MAX-1, Andersson et al

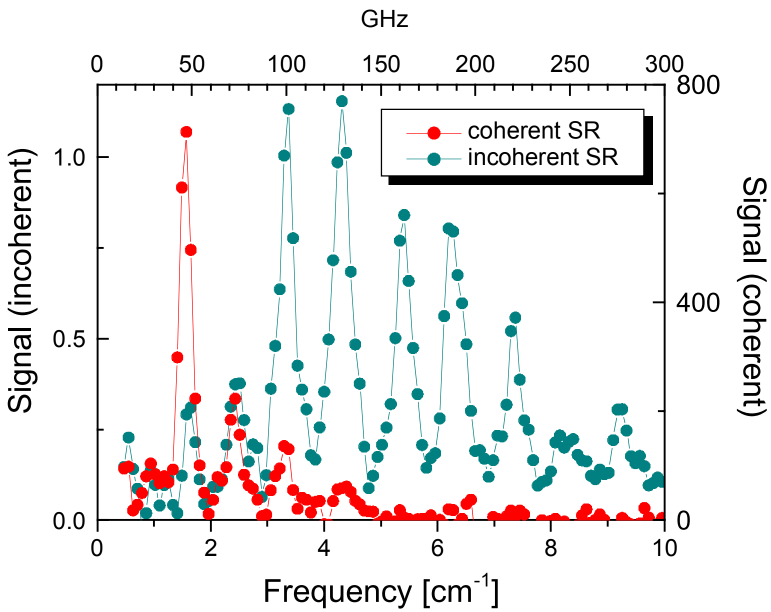


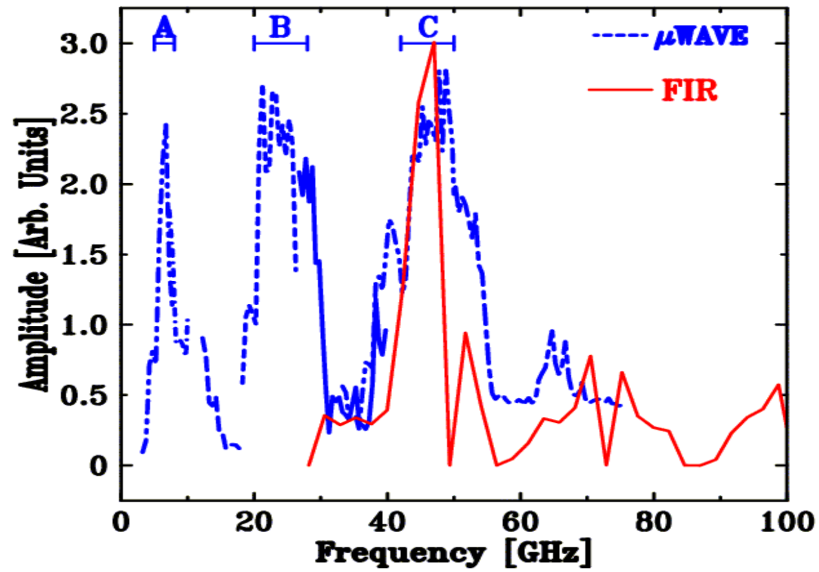


NSLS VUV

- Emission peaks at 2–10 cm^{-1}
- Very broad-band
- Coherent and incoherent differ
- P_{coh}/P_{incoh}~10^3–10^4
- $P_{coh} \sim N^2$ well above N_{thresh}

More Interferometry and MW



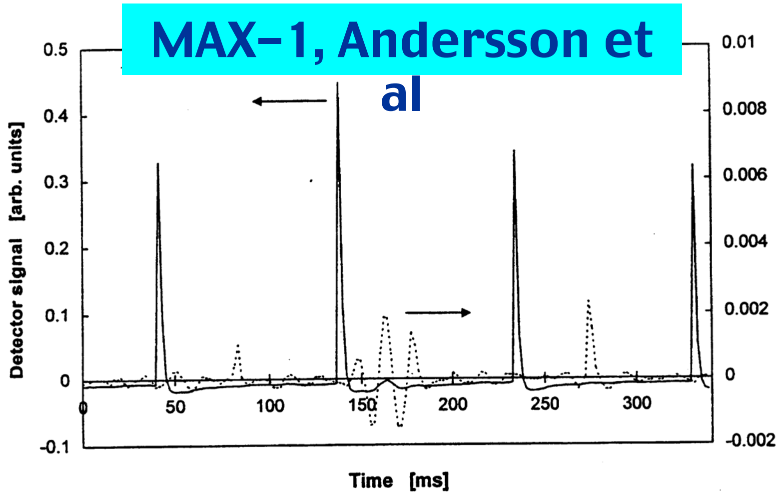


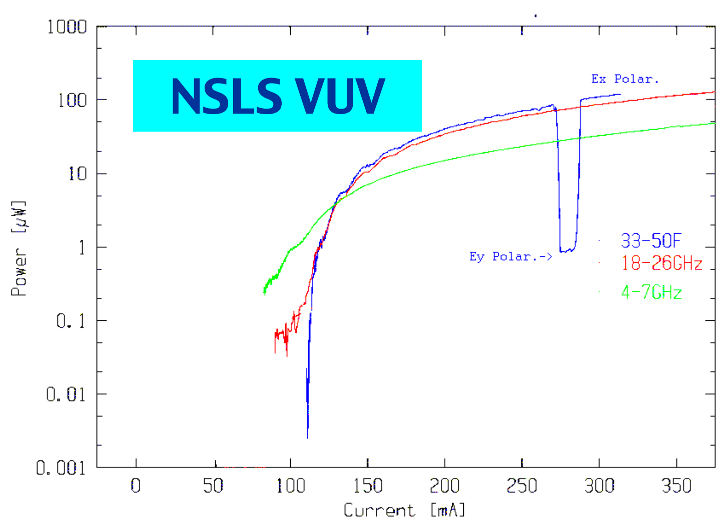
NSLS VUV U12IR data

G.L. Carr, S.L. Kramer et al

- Complex spectral structure
- Agreement of different techniques
- Fringe pattern due to photon reflections in the beam-pipe
- Ratios: pros and cons

Polarization Measurements





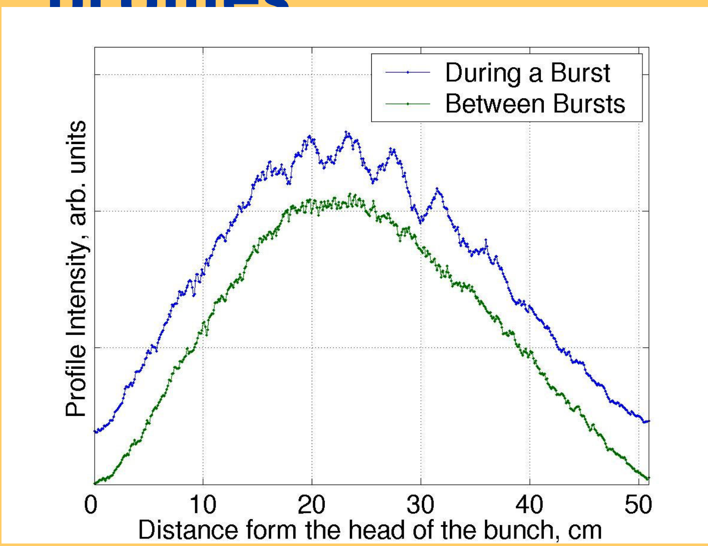
- Possible with interferometry or MW detection techniques
- Emissions are often polarized in the bending plane Ex/Ey>100
- Consistent with ~~CSR~~
- Low frequency emissions at NSLS are not polarized -> CSR

"e-beam Measurements"

- Previous measurements characterize "very -FIR photons" emitted from the beamline
- What's happening with e-beam?
- BPM signal analysis
  - RF/MW techniques applicable
  - Typically run out of BW
- Average bunch shape measurements
- Instantaneous bunch shape (resolve bursts)

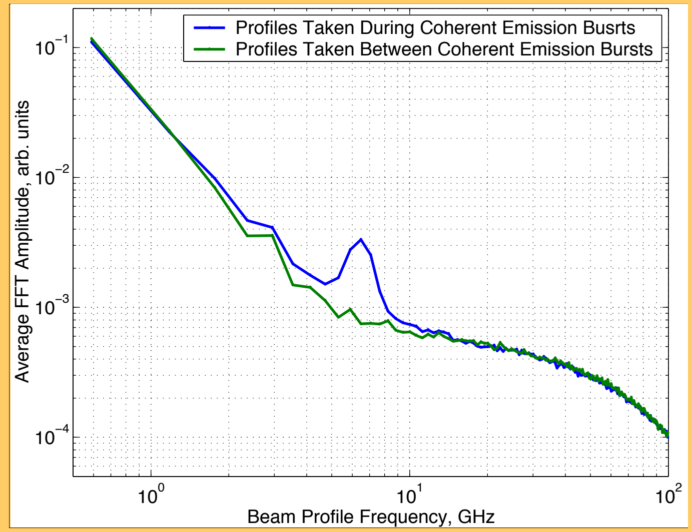
NSLS VUV Ring Streak Camera Results

- **Two 18-turn-average profiles**



- **Frequency agrees with $Z_{//}(\omega)$**
- **Microbunching due to microwave instability? CSR**

- **300 profile Fourier Transform averages**



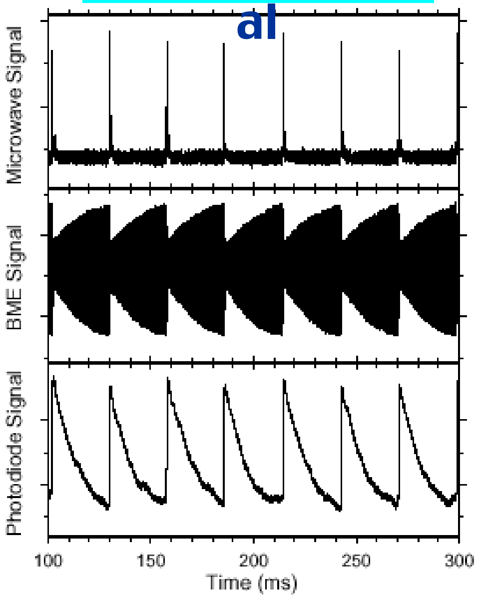
- **Search for higher frequency modulation is still in progress**

Conclusion

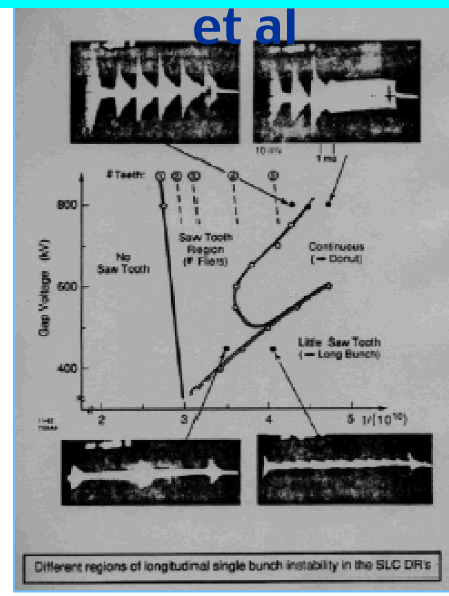
- No one-size-fits-all experimental technique
- Vastly different rings yet amazing similarities in burst structure, spectra, parameter dependence
- Reported $P_{coh}/P_{incoh} \sim 10^4$
- Spectral content may be complex
- Low frequency coherent emissions are not CSR
- Some evidence of non-CSR impedance causing low frequency emissions/beam modulation

Final Thoughts

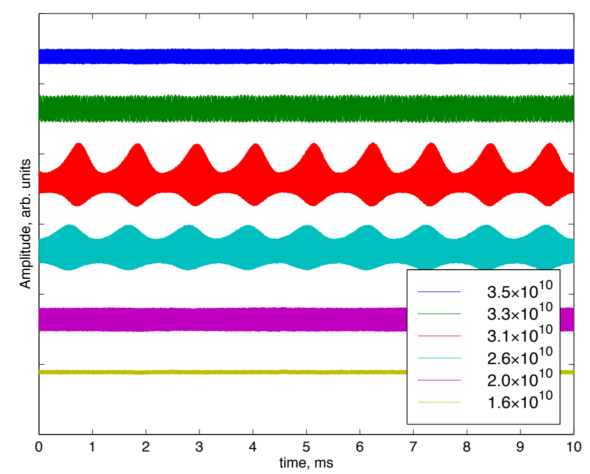
SURF, Arp et al



Old SLC DR, Krejcik et al



New SLC DR



- Coherent bursts go together with the saw-tooth instability
- There is always a non-bursting region at higher intensity
- Not obvious that low α and micro-Amps of I_b is the only way to get “steady state” CSR